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SOME NEW POINTS IN DINICHTHYID OSTEOLOGY.

C. R. EASTMAN.

THE standard of comparison for all Arthrodiran fishes is the typical genus Coccosteus Agassiz, the osteology of which is known in the minutest detail. As our knowledge of allied genera increases, the more closely do we find them connected by intermediate stages, and the better are we able to trace the sequence of modifications passed through by them. The group of Dinichthyids (*Dinichthyinæ*) is a large one, and contains many bizarre forms, most of which are still very imperfectly known. But when their characters shall have been fully investigated, the wide range of variation manifested by them will be found reducible to order, and the whole promises to constitute one of the most interesting evolutionary series known among fossil fishes.

The characters of Dinichthys have been made out very gradually, through slow, persistent effort, but we are still far from having a complete knowledge of any one species. The only one in which the cranial osteology has been worked out with tolerable accuracy is *D. intermedius*, although the heads of *D. terrelli* and several smaller forms are not uncommon and are not always ill-preserved. Tardiness in acquiring information was inevitable, however, in the case of the Ohio Dinichthyids, owing to their prevailing mode of occurrence in concretions, with attendant obliteration of details. The supply from other localities has been meager, and is preserved in widely scattered institutions. Even where the Ohio material has been concentrated in some of our leading museums, facilities for investigating it have often been lacking. Under such conditions progress has necessarily been slow.

Reference was made in the August number of this journal (p. 556) to the discovery of several well-preserved crania of *Dinichthys pustulosus* from the Hamilton Limestone, which prove this species to be the most primitive member of the genus known. It is now proposed to illustrate its osteology more fully, and at the same time offer comparisons with other Arthrodires, including Coccosteus and Titanichthys. The two last-named genera, in fact, may be taken to represent the extreme limits of the family *Coccosteidæ*. For in whatever grouping Dinichthys be placed, be it of subfamily rank or otherwise, there is no question that Titanichthys should accompany it; and the relations of Dinichthys to Coccosteus are seen to be so intimate, we are unable to remove it from the same family. On the other hand, the separation of Macropetalichthys and some other Arthrodires from the *Coccosteidæ*, where they are now commonly placed, seems advisable.

Dinichthys pustulosus.

Besides the examples of this species preserved in the Museum of Comparative Zoology, of which the most perfect cranium is from Rock Island, the writer has been able to consult a number of fine specimens belonging to Messrs. Teller, Monroe, and Slocum, of Milwaukee, two from the Cedar Valley Limestone belonging to the State University of Iowa, and one belonging to the United States National Museum, of which last an illustration is given herewith (Fig. 1). The original of this was kindly loaned by Mr. F. A. Lucas, curator in charge of comparative anatomy; the Iowa material by Prof. Samuel Calvin; and the Milwaukee specimens by their owners, to all of whom grateful acknowledgments are hereby rendered.

The larger and more specialized species of Dinichthys and Titanichthys have a nearly flat cranium, and the surface of all the derm plates is smooth, these probably having been covered in life by the integument. The cranium of *D. pustulosus*, on the other hand, is strongly arched from side to side, and, like all the body plates, is covered with innumerable small rounded tubercles, slightly stellate at the base. A narrow band along the sutures, however, is generally striated and destitute of tubercles; and the suture lines themselves are undulatory. In all of these particulars the species bears a great resemblance to Coccosteus, yet even more striking is the similarity in pattern of the head bones and arrangement of the sensory canals. The transitional characters are so apparent as to preclude the idea of assigning the two genera to separate families.

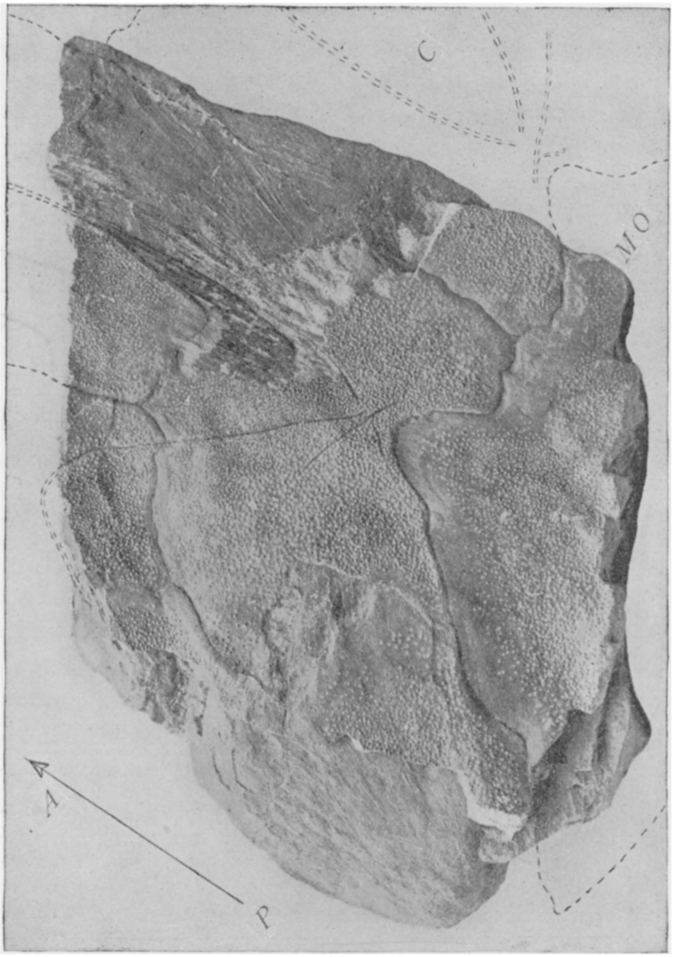

FIG. 1. — *Dinichthys pustulosus* Eastm. Hamilton Limestone, Milwaukee, Wisconsin. Fragment showing sutures, sensory canals, and finely tuberculated ornament of cranium. Original in U. S. National Museum (Cat. No. 19). Direction of longitudinal axis indicated by the arrow; lettering as in Fig. 2. × ⅗.

An attempt is made in Fig. 2 to represent the cranial shield of *D. pustulosus* as if flattened out, thus facilitating a comparison with other diagrams. It is intended at some future time to reproduce a large scale photograph of the Rock Island cranium, on which most of the sutures and sensory canals are visible, in order to show the appearance in perspective of a form so highly arched from side to side as this. The most noteworthy feature regarding the sutures in this species is their prevailing undulatory outlines. No other Dinichthyid has them so sinuous, and even those of Coccosteus are less so in some regions. Beginning with the median occipital element (*MO*), we observe that it is longer and less tapering than in other species of Dinichthys, and is of about the same relative proportions as in Coccosteus. But instead of being slightly sulcated anteriorly, as in *C. canadensis* and some other species, it is deeply lobed, and the anterior boundary is decidedly wavy. Immediately in front of the median and external occipitals lie the paired central elements (*C*), which exhibit almost identical relations with those of Coccosteus. Their anterior and lateral margins are more wavy than in Coccosteus, but their common longitudinal suture is less so. In advance of the centrals are the large preorbital plates (*PrO*), which are separated in front by presumably two median elements, the pineal (*P*) and rostral (*R*). It was impossible, however, to determine the relations of these two plates from any of the specimens that came under the writer's observation, beyond that the pineal seems to be very narrow and without visible perforation. Likewise the boundary between pre- and postorbital plates is indistinct throughout the greater portion of its length; but it is believed that all of the remaining sutures are accurately delineated in the figure.

One of the most marked points of similarity between *D. pustulosus* and Coccosteus is the fact that the central elements (*C*) are in contact with one another mesially throughout their entire length. These plates are similarly united in Phlyctænaspis, Brachydirus, Homosteus, and Titanichthys, which are sufficient to establish it as a general rule throughout the family *Coccosteidæ*. But an exception would appear to be furnished by *D. intermedius* and *D. terrelli*, provided we can depend upon the descriptions of earlier writers as trustworthy. The

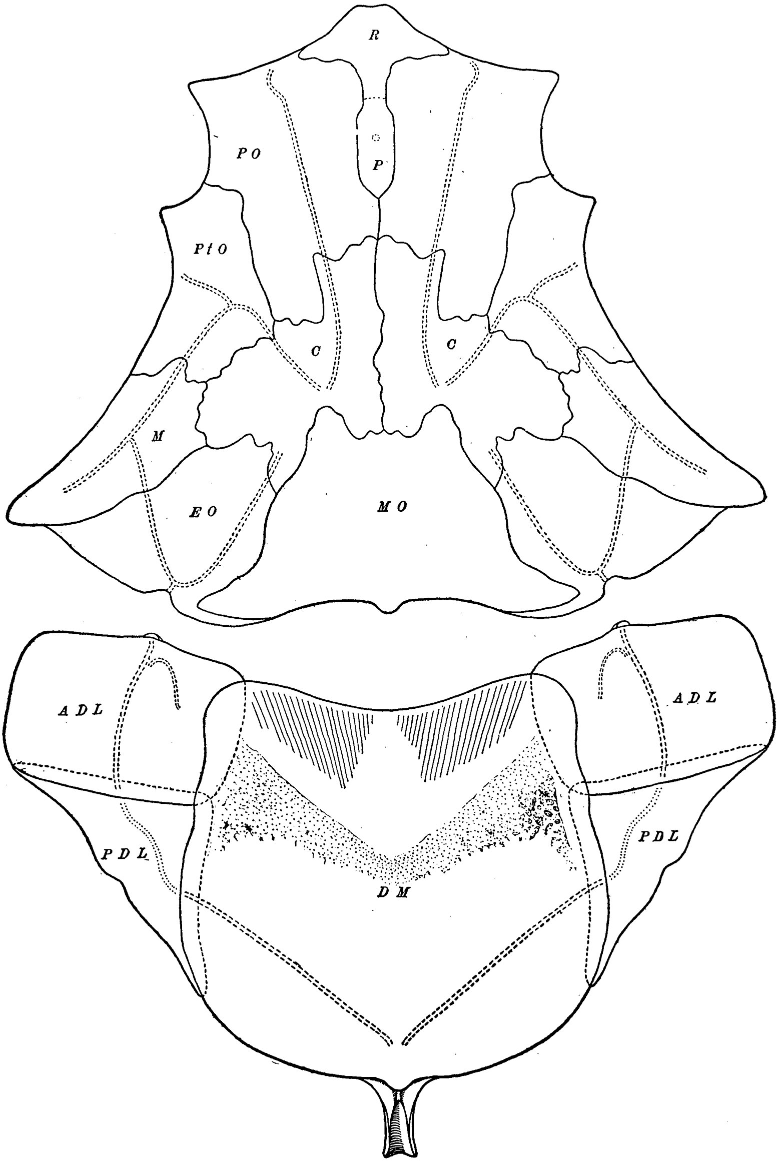

FIG. 2. — *Dinichthys pustulosus* Eastm. Hamilton Limestone, Wisconsin. Diagram showing cranial and dorsal shields. × ¼. *Abbreviations: ADL,* antero-dorso-lateral; *C,* central; *DL,* dorso-lateral; *DM,* dorso-median; *EO,* external occipital; *M,* marginal; *MO,* median occipital; *P,* pineal; *PDL,* postero-dorso-lateral; *PO,* preorbital; *PtO,* postorbital; *R,* rostral.

restorations of the cranial shield in these species, as given by Newberry, Claypole, and Dean, all show a subdivision of the space corresponding to the centrals in Coccosteus into two paired plates, which are designated as "parietals" and "frontals." Claypole,[1] in describing the skull of *D. intermedius*, speaks as follows regarding the frontal plates : "This area is well outlined in Dr. Newberry's figures, where its boundaries are much more clearly marked than in the specimen now described." And again, in regard to the "parietals" he says : "Judging from the conventional form which he has given to this plate in his restoration, its outlines cannot have been clearly defined in the specimen which Dr. Newberry studied. Instead of the small and elliptical area which he has assigned to it, it has a large size and an irregular outline." We see from this that Newberry's specimen (or specimens) failed to show perfectly the boundaries of one of the subdivisions of the central plate, and Claypole's failed to show the other. It is fair to allow that appearances may have been suggestive of a division in some examples ; but the writer can only state from his personal experience that he has not yet been able to observe such a division of the centrals in *D. intermedius* and *D. terrelli*, and is positive that none exists in *D. pustulosus*. We will revert to this matter again under the head of the first-named species.

The arrangement of sensory canals in *D. pustulosus* is very much the same as in other species of this genus, except that they are more curved, especially the preorbital canal, thus recalling the conditions in Coccosteus. In the latter genus, but not in Dinichthys, a lyra is formed in the middle of the shield by the disposition of sensory canals on the central elements. That is to say, the canals following the boundary of the median occipital bend around towards each other, and a transverse channel connects the point of origin of the pre- and postorbital canal systems. A survival of this lyrate arrangement exists in *D. pustulosus*, in that occasionally one or more short, slightly curved, independent canals are seen to originate below the middle of the central plates and sweep inwards and downwards not far in advance of the median occipital element, sometimes even traversing it for a short distance (Fig. 1). Similar isolated canals occupy the same position in the crania of Titanichthys (Fig. 4), and very often a reminiscence of them appears in *D. terrelli.*

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[1] Claypole, E. W. The Head of Dinichthys, *Amer. Geol.*, vol. x (1892), pp. 199–207.

The canals traversing the external occipitals form a Y, whose descending branch passes across the articulating condyle of the antero-dorso-lateral, and thus emerges upon the dorsal system of body plates. In Coccosteus the canal traversing the antero-dorso-lateral bifurcates as soon as it crosses the condyle, a branch running toward either of the posterior angles of the plate, and that running toward the postero-internal angle is continued upon the dorso-median plate. In Dinichthys and Titanichthys there is no such bifurcation on the antero-dorso-lateral, but the canal is single, extending backward along approximately the middle of the plate, and thence on to the postero-dorso-lateral. Nevertheless, in *D. pustulosus* a reversion toward Coccostean conditions is occasionally met with, inasmuch as the antero-dorso-lateral may have a second short canal, ending blindly, as shown in Fig. 2.

None of the American Dinichthyids have heretofore been known to have the dorso-median traversed by sensory canals, although this condition exists in a small European species, described as *D. pelmensis.*[1] But the dorso-median of *D. pustulosus* bears distinct traces of canals, albeit the grooves are narrower and shallower than those of the antero-dorso-lateral plate. They extend obliquely backward from the point where they leave the postero-dorso-lateral and terminate just before reaching the median line of the shield. Only one example of the postero-dorso-lateral has thus far been encountered,[2] and as it lies with its external surface embedded in the matrix, the course of the canal system across this plate (indicated on the diagram by dots instead of dashes) has yet to be verified. Plates that are evenly embedded like this are likely to have their thin edges preserved entire, thus showing the full extent of the overlapped area. We know this condition very well for the element in question, but the same cannot be said for the antero-dorso-lateral, whose thin overlapped edges are invariably broken away in all species. Accordingly, we have had to follow only the broken margin in drawing the outlines of this plate in Figs. 2 and 3, although without doubt the area overlapped by the dorso-median on the one side and clavicular on the other was much greater. The union of the dorso-lateral plates in this species is one of simple overlap, and not by pegs and sockets, as in *D. terrelli* and *D. intermedius.* Here again the resemblance is with Coccosteus.

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[1] *Bull. Mus. Zool.*, vol. xxxi (1897), Pl. II, Fig. 4.

[2] Now deposited in the Milwaukee Public Museum with the rest of Mr. C. E. Monroe's private collection, of which it forms a part.

Through an oversight, the markings on the antero-dorso-lateral, where the overlapping clavicular came in contact with it, were omitted from the diagram, but are essentially as shown in Fig. 3. One example of the clavicular was obtained by Mr. Teller near Milwaukee. It is an extremely heavy plate, bifurcated anteriorly as in other species and tuberculated on its external surface.

Another point of resemblance to Coccosteus is observed in the slight anterior emargination of the dorso-median. The exposed area between this plate and the occiput was very small in comparison with other Dinichthyids. As shown in Fig. 2, the forward part of the dorso-median is quite destitute of tubercles, and the demarcation of the barren area takes place along an oblique line extending from the middle of the shield toward either of the antero-external angles. This we regard as indicative that the anterior portion of the plate was buried beneath the integument. The median keel on the inferior surface is well developed and terminates in a massive posterior process, which attains a length of over 12 cm. in the adult. It depends at a greater angle with the shield than in the larger species, being in fact almost vertical. In this respect it agrees with other primitive tuberculated forms, such as *D. livonicus, D. trautscholdi, D. pelmensis,* and presumably also *D. ringuebergi.* The average length of the shield in the median line, exclusive of process, is about 21 cm. in the adult, and maximum width about 36 cm.

Dinichthys intermedius Newberry.

Fig. 3 shows the arrangement of cranial and dorsal shields in this species, as determined from specimens in the Museum of Comparative Zoology. The diagram of the head is based on a cranium that has already been described with considerable detail by Claypole,[1] and his figure was copied with slight modifications in a former paper by the writer.[2] The present figure does not differ materially from either of the preceding ones, except that the boundaries of a few plates are slightly altered, the position of the pineal foramen is indicated, and the suborbital and opercular ("postmaxillary" Newberry), which do not properly form a part of the head shield, are here omitted. A supernumerary sensory canal, thought by Claypole to extend along the boundary between the pre- and postorbital plates near the orbits is also suppressed, as nothing but the suture was observed in this region. The pineal plate has been shortened somewhat, but its outline is still conventionalized after Claypole's figure, the element itself being missing from the specimen. In *D. terrelli* and *D. pustulosus* this plate is relatively shorter and narrower than here represented, but owing to its tenuity, is seldom well preserved.

As already remarked, the writer has not been able personally to observe a division of the central element into two plates, termed by Newberry, Claypole, and others the "parietal" and "frontal." The boundary, as depicted by Claypole, has been allowed to stand in dotted lines on the present figure, but the two portions occupying the space of the central are designated C^1 and C^2, instead of by the misleading terms commonly applied to them. If two plates could actually be shown to exist here, the terms *central* and *precentral* would be decidedly more fitting. It is true that in Phlyctænaspis a division of the marginal into two separate elements, angular and marginal proper, has been noticed by Traquair;[3] and unless von Koenen[4] has mistaken the initial portion of the preorbital canal for a suture, a similar

[1] *Loc. cit.* (1892), pp. 199–207.

[2] *Bull. Mus. Comp. Zool.*, vol. xxxi (1897), Pl. I, Fig. 1.

[3] *Ann. Mag. Nat. Hist.* [6], vol. xiv (1894), p. 369.

[4] *Abhandl. Akad. Wissensch. Göttingen*, Bd. xl (1895), Taf. II, Fig. 6.

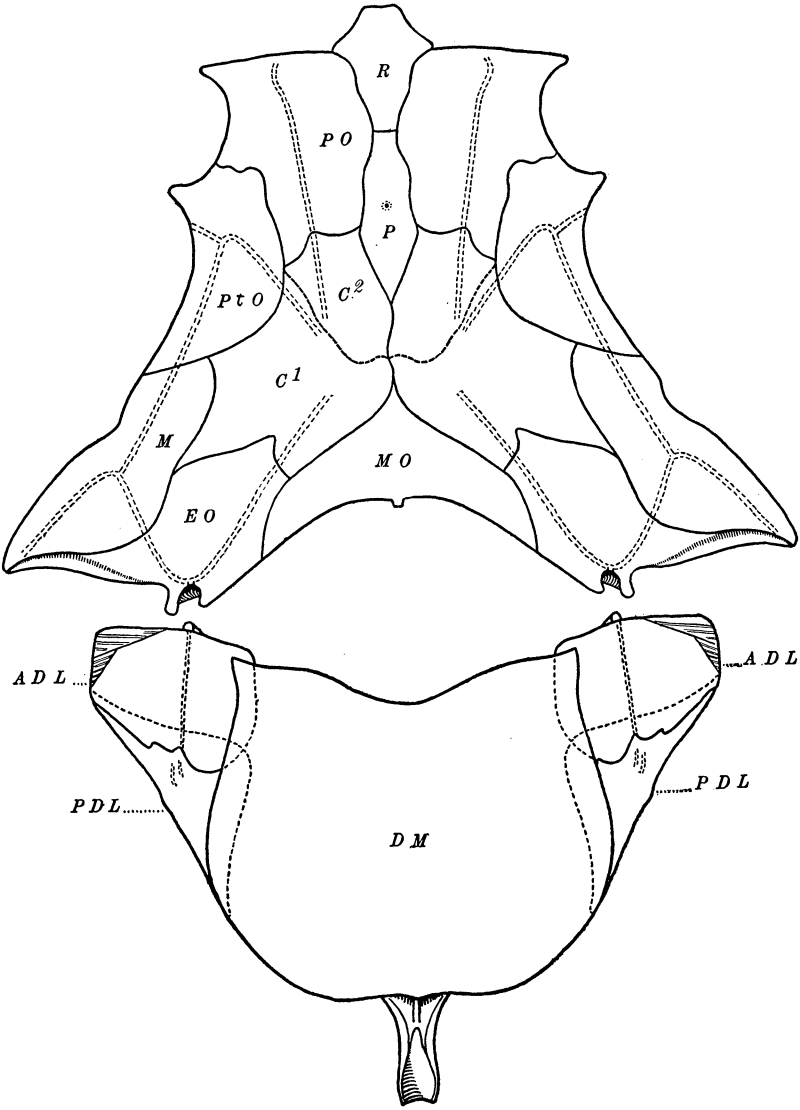

FIG. 3. — *Dinichthys intermedius* Newb. Cleveland Shale, Lorain County, Ohio. Diagram showing cranial and dorsal shields. × ¼. Lettering as in Fig. 2.

division of the central element of Brachydirus into two plates is to be inferred. But owing to the poorly preserved condition of von Koenen's material, a confusion of sensory canals and sutures was easily possible; and a comparison of the remaining figures, given by this author, leads us to believe that the central was in reality undivided in Brachydirus; that is to say, its relations are the same as in Coccosteus and *D. pustulosus.*

There is a chance, therefore, that the recognition of a precentral plate in Dinichthys depends upon faulty observation, and we are strongly of the opinion that no *bona-fide* sutures were ever seen on the dorsal surface cutting off a portion of the central, as earlier writers would have us believe. But on examining the visceral surface of the head shield, one can easily understand how the solidifying crescentic ridge (seen one on either side of the median line and abutting against the equally heavy ridge of the median occipital), which stands in marked contrast to the thin forward extension of the central, might give one the impression of a distinct element.[1] The function of these ridges is to strengthen the base of the skull, and it would be strange, indeed, if they were cut through by sutures visible from below, where such are generally more obliterated than on the dorsal surface, and yet are not apparent from above. It is true that the ridges rise very abruptly, but although their separation from the central plate proper may seem to be indicated by some specimens, owing to difference in texture of bone substance, we regard it as very improbable that a suture exists here. Inasmuch as the central is a single element in *D. pustulosus,* it would certainly be anomalous not to find it entire in all species of this genus.

The median occipital element of *D. intermedius* is acutely pointed in front, with the apex extending forward between the centrals, as in Phlyctænaspis and Brachydirus, but this is an exception to the general rule in Dinichthys and Titanichthys. The anterior margin of the median occipital in *D. terrelli* resembles that of *D. pustulosus,* except that the indentations are shallower. Both *D. intermedius* and *D. terrelli* have the nuchal margin strengthened below by a heavy ridge which extends from the median line obliquely outward and backward on either side as far as the sockets of the exoccipital plates. In *D. pustulosus* the ridges on the under surface of the occipital and central elements are not nearly so heavy as in other species of Dinichthys, and the formation of the double socket in the middle of the nuchal line is simpler. This peculiar structure is supposed by Claypole to mark "the place of insertion of some powerful muscle or ligament that connected the head with the rest of the body." It is well shown in a number of Newberry's figures of Dinichthys and Titanichthys.[1] The bone is extremely dense in this region, and the thickness of the cranium is greater than in any other place. Hence, fragments that have been rolled about or subjected to weathering often become reduced so as to leave nothing but this portion of the occiput.

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[1] *Cf.* Newberry, J. S. Palæozoic Fishes of North America, *Monogr. U. S. Geol. Surv.*, vol. xvi (1889), Pl. LII, Fig. 1.

Dinichthys terrelli Newberry.

This species is numerically the most abundant of American Dinichthyids, and the largest collection of its remains is preserved in Columbia University.[2] The writer, having but one head at his disposal in the Agassiz Museum, has not essayed to figure the cranial osteology, but we may say it does not differ materially from that of *D. intermedius*. The Cambridge specimen shows no evidence of a division of the central into two parts, but the solidifying ridges on the under surface are detached from the cranial bones for a slight distance anteriorly, thus producing the semblance of separate plates.

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[1] *Loc. cit.* (1889), Pl. I, Fig. 2; Pl. IV, Fig. 2; Pl. VIII, Fig. 4; Pl. LII, Fig. 1.

[2] Since this article was written the writer has enjoyed the privilege, thanks to the courtesy of his friend Dr. Bashford Dean, of looking over the greater part of Professor Newberry's collection, which has recently been stored in cases in Schemerhorn Hall. No specimens could be found to prove the existence of "parietal" and "frontal" elements, and the conclusion is that they do not occur. A large example of the antero-dorso-lateral with entire margins (embedded in shale) proves that this plate extended underneath the dorso-median and clavicular elements for a distance hitherto unsuspected, the covered area being even greater than the exposed. Newberry's figures of the clavicular in this species are seen to be based upon an imperfect specimen, the superior margin of which has been artificially restored, and is to a certain extent misleading. On the other hand, the collection contains some unusually perfect examples of this plate, which certainly deserve to be figured. There is also abundant evidence to show that the normal condition of the ventro-median plates in *D. terrelli* was one of simple overlap, but, in the adult stage, fusion of the two elements may progressively set in.

The relations of the dorso-lateral plates have been sufficiently treated in former papers, in one of which the writer lamented the fact that no plates corresponding to the laterals of Coccosteus have as yet been brought to light. It seems really quite remarkable that the plate which students of Dinichthyid anatomy have been looking for so long, and has heretofore been regarded as missing, should finally turn out to be one we are all familiar with, and has simply been masquerading under another name these many years. We refer to the "*clavicular*," so named because it was supposed to have formed part of the shoulder girdle. Different writers have made various guesses as to its position on the body. Newberry[1] turned it end for end, its bifurcations being supposed by him to have embraced the antero-dorso-lateral. Claypole[2] considers — "that it was external and ventral can hardly be doubted," — and also confuses rights and lefts. Dean[3] pictures it in his frontispiece as standing vertically and supporting the mandibles.

According to our interpretation, the plate in question has nothing to do with a shoulder girdle, and there is absolutely no evidence that the Dinichthyids possessed paired appendages. The clavicular is in the form of a carpenter's square, roughly speaking ; one arm is bifurcated and extends anteriorly and outwardly, the other is single, broad, and flat, and is directed nearly at right angles with the longitudinal axis of the body. The broad arm is homologous with the *anterior lateral* of Coccosteus, and occupies a corresponding position. The heavy ridge on its under side fits into a depression running along the front margin of the antero-dorso-lateral, and its flat expansion overlies a large area of the latter plate, as shown by characteristic markings (see Fig. 3). The same arm also extends across the interval between cranial and dorsal shields, overriding a rounded flange at the base of the external occipital. The sensory canal running down to the posterior apex of the marginal plate is continued on to the clavicular, being traceable along the margin of the transverse arm as far as the right angle. Fitting in behind this arm and abutting against the postero-dorso-lateral, as shown by impressions on both, was the *posterior lateral*, a plate not hitherto identified as such. It may be that Newberry's supposed "hyoid (?)" plate[1] occupied this space, but further comparisons are necessary to establish the truth of this inference.

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[1] *Loc. cit.* (1889), p. 142.

[2] *Rep. Geol. Surv. Ohio*, vol. vii (1893), p. 110.

[3] *Fishes, Living and Fossil.* New York. 1895.

The side plates of the body being now fully accounted for, it may be asked why the name anterior lateral is not substituted instead of "clavicular." The answer is that only one arm of this plate corresponds to the anterior lateral of Coccosteus, while the bifurcated arm represents something entirely different. Hence we must either go on calling the whole structure clavicular, or invent a new name for it; we prefer the former course, although technically the term is a misnomer. It will require a separate article to illustrate the relations of the bifurcated arm, and we will pass over this for the present, remarking only that the inner branch consists of a long thin blade which is probably homologous with the *interlateral* of Coccosteus, and the external curved branch has articulated to it distally a peculiar warped plate, supposed to have formed part of the modified branchiostegal apparatus.

The effect of this orientation of the clavicular is to revolutionize previous notions as to the form of cross-section in Dinichthys and Titanichthys. Instead of being deep-bodied creatures, it is now plain that the more specialized species, with their flat dorsal and abdominal shields and excessively wide cranium, must have had almost ray-like proportions, and this depression of body was no doubt correlated with bottom-feeding. We observe also, which was not suspected before, that the plastron was not in contact with other dermal plates, and covered a relatively small portion of the abdomen. The flat portion of the suborbital probably had a continuous slope with the head shield, its inclination (and also that of the clavicular) being more nearly horizontal than vertical. These relations can best be shown in a side-view restoration, which we hope to present at a subsequent time.

The only writer to attribute an opercular plate to Dinichthys is Professor Newberry, who figures it (under the designation of "postmaxillary") in his restoration of *D. intermedius*[1] as if suturally united with the suborbital. We have never observed traces on the suborbital indicating a connection with a posterior element, and as its flat expansion reaches in *D. terrelli* almost as far as the posterior angle of the head shield, the opercular either did not occur in this species, or is represented by the hinder part of the suborbital's expansion. *D. intermedius*, however, had a relatively shorter suborbital than the larger species, and theoretically it ought to be followed by a separate plate. Newberry's supposed "eye capsules,"[2] which are preserved in a fairly constant position on the visceral side of the skull, we interpret as *nasal* capsules.

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[1] *Loc. cit.* (1889), Pl. V, Fig. 3.

Titanichthys agassizii Newberry.

The cranium upon which this species is founded is unique, and forms one of the principal treasures of the Museum of Comparative Zoology. The mandibles belonging to it, however, are preserved in the Museum of Columbia University, together with all the specimens of *T. clarkii* that have been collected up to within the last few years.

Newberry describes the head of Titanichthys as being "triangular in outline, over four feet broad at the occiput, the nasal portion imperfect in all the specimens known, and the surface smooth or granular, marked by incised lines which form a pattern indistinctly shown in the specimens yet examined." He made no attempt to describe the osteology in either of his species, and the head of *T. clarkii* was not even figured. The "incised lines" (sensory canals) are shown after a fashion in his representation of *T. agassizii*,[3] and their arrangement is still more imperfectly shown in the rough diagrams given by Cope[4] of the same species. As a matter of fact, the sensory canal system is indicated with tolerable clearness on the original head of *T. agassizii*, and enough of the sutures are traceable to give a pretty fair idea of the arrangement of cranial plates. The boundaries of the latter are represented in the accompanying diagram (Fig. 4) by continuous lines as far as they can be made out with certainty, and are dotted in where more or less obscure. Sensory canals are indicated by the usual convention of double dotted lines. The posterior and lateral margins of the skull are entire; the part broken away includes a portion of the preorbitals and pineal and the whole of the rostral (or "ethmoid") plate. It is very evident, however, that the head was more elongated from side to side than in an antero-posterior direction, which is opposite to the usual rule. It is also almost perfectly flat, instead of being transversely arched.

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[1] *Loc. cit.* (1889), Pl. LII, Fig. 2.

[2] *Ibid.*, Pl. VII, Fig. 2.

[3] *Ibid.*, Pl. I, Fig. 1.

[4] On the Characters of Some Palæozoic Fishes, *Proc. U. S. Nat. Museum*, vol. xiv (1891), Pl. XXXI, Fig. 6.

In consequence of the huge size of the head and thinness of the plates, rigidity could only be attained by a nearly complete fusion of the cranial elements, and this rendered the artifice of dovetailing unnecessary. Nevertheless a vestige of the usual interlocking condition remains in the anterior boundary of the central element, where there are a few moderate-sized undulations. Presumably the centrals met each other in the middle along a wavy line, as mechanical principles would seem to require, but the suture itself is now almost wholly obliterated. There is likewise no sort of indication that the space homologous with the central was divided into two components. The pineal plate seems to have been of elliptical outline and longest in a transverse direction. It is extremely attenuated at its lateral edges, where it has been somewhat broken away. Here and along the antero-external margins of the central were the thinnest regions of the cranium, the bone being considerably less than .5 cm. through. The pineal foramen is enclosed in an elliptical capsule of very dense tissue, and opens on the dorsal surface in a circular orifice. An interesting fragment in the collection of Dr. William Clark, of Berea, Ohio, shows that this opening was covered by a thin opercular plate lying loose on the upper surface and undoubtedly movable in life. In another specimen the foramen is seen to be double, the two being separated a slight distance sidewise.

The rostral plate, termed also "nasal" and "ethmoid" by different authors, has been entirely broken away from the type specimen, together with the forward portions of the preorbital plates. The margin of the latter extends for such a distance inwardly in advance of the orbits as to suggest that the head was foreshortened in the manner shown by the diagram. It is possible, of course, that both rostral and pineal plates were transversely elliptical, instead of the pineal only, as here represented; but in either case the effect on the preorbitals was to give them a very different aspect from the usual condition in the *Coccosteidæ.* These three plates are the only ones which differ markedly from their homologues in Dinichthys.

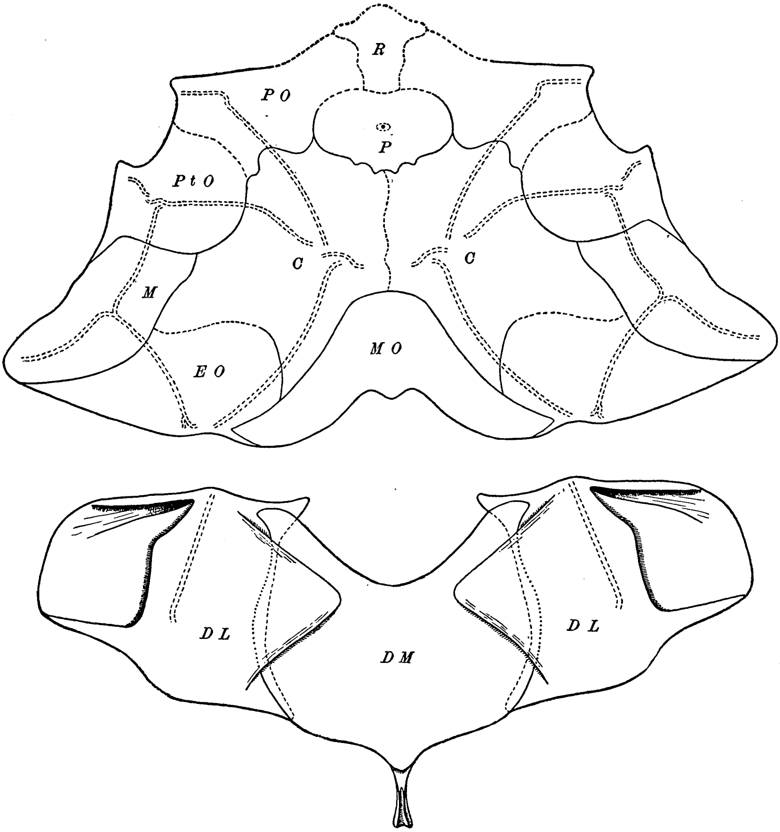

FIG. 4. — *Titanichthys agassizii* Newb. Cleveland Shale, Ohio. Diagram showing cranial and dorsal shields (partly restored). × $\frac{1}{11}$. Lettering as in Fig. 2.

Newberry's figures show the formation of the nuchal sockets on the under surface of the occiput very clearly. They are quite deep and divided by a thin longitudinal septum, but are not bounded below by a transverse septum, as in *D. terrelli.* The thickness and compact texture of the bone substance in this region are very remarkable, as noted above. The nuchal ridges are broad and massive, but not nearly so prominent as in Dinichthys; and the median longitudinal ridges, together with those belonging to the central ("parietals"), which are so conspicuous in *D. terrelli* and *D. intermedius*, are here altogether lacking.

The arrangement of sensory canals is sufficiently indicated by the diagram, and the articulation of cranial and dorsal shields is so familiar from Newberry's writings that we may pass over these topics. We cannot agree with the latter author, however, that the hinge joint permitted a lateral as well as vertical motion of the head shield, and even the vertical motion must have been restricted in large measure by the overlapping claviculars.

The outline of the dorso-median is reduced from a photograph purporting to be of *T. clarkii*, but, as will be shown presently, there are good reasons for believing it to belong to this species. Not only does it overlap the inner edges of the dorso-lateral plates (for a distance not determinable from the specimen at hand, but probably greater than shown in Fig. 4), but it in turn passes underneath a heavy flange which is given off from the superior surface of the dorso-laterals. The edges of the dorso-median are thus received into a deep groove formed by the side plates; and in another species, as we shall see, the articulation was still further complicated. How far the flange extended backward over the surface of the dorso-median cannot be told with certainty, as it is broken off in the manner shown by Newberry's illustrations.

The term *dorso-lateral* is here used to include the mass of bone contiguous to either side of the dorso-median, the components of which are apparently fused. That two elements are concerned in the formation of this apron-like expanse is patent from a number of features, such as the arrangement of vascular canals, tenuity of bone substance along the presumable line of fusion, and nature of the free margin corresponding to the postero-dorso-lateral on the right-hand side of the specimen; but no distinct evidence of a suture line is to be observed. It will be remembered that Macropetalichthys also affords an instance of fused dorso-laterals.[1] On the diagrams given herewith all exposed or overlapping margins are shown by continuous lines, and underlapping margins by dotted lines; round dots are used where the dorso-median passes under the flange of the dorso-laterals, and dashes along the overlapped inner margins of the latter plates.

In the region of articulation with the head shield the dorso-laterals are extraordinarily heavy. The thickness even exceeds that of the occiput, being between 5 and 6 cm. through. Great rigidity, however, was necessary in order to hold the claviculars firmly in place. The latter were of huge proportions, but composed of a relatively thin shell of bone. A large area of the dorso-lateral was overlapped by the clavicular, as indicated by shading in Fig. 4, and the heavy ridge on the visceral surface of the latter plate was received into a corresponding deep depression along the anterior margin of the dorso-laterals. Very excellent examples of the clavicular, belonging probably to the next species, are to be seen in the Columbia and Oberlin Museums.

Titanichthys clarkii Newberry.

The dorso-median shown in Fig. 5 is reduced from one of Newberry's illustrations,[2] the original of which the writer has failed to see, although it is said to be still preserved in the Museum of Columbia University. It has not been previously recognized as a dorso-median, Newberry having figured it in an inverted position and referred it to the "under side of the body or head." The dorsal aspect is here represented, and we suspect that the visceral side was embedded in the matrix, since otherwise Newberry could not have failed to observe the median carina. Its slender terminal process must also have been broken off before he saw the specimen.

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[1] *Amer. Nat.*, vol. xxxi (1897), p. 497.

[2] *Loc. cit.* (1889), Pl. III, Fig. 1, described on p. 135.

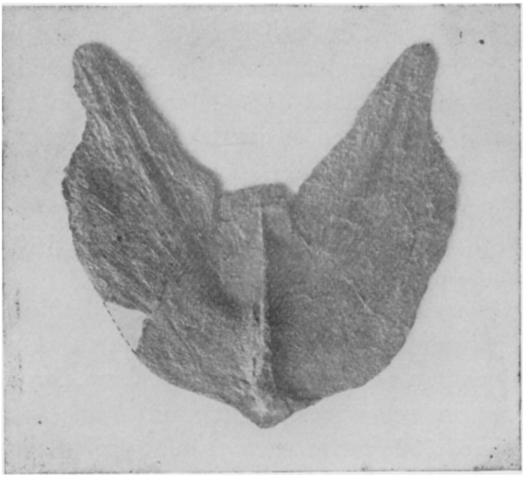

FIG. 5. — *Titanichthys clakrii* Newb. Cleveland Shale, Ohio. Dorso-median plate lacking median anterior spine and cranial process. (Reduced from a figure by Newberry.) × $\frac{1}{21}$.

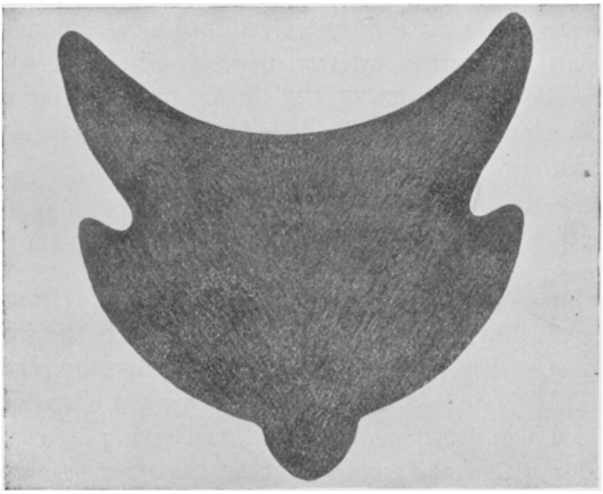

FIG. 6. — *Titanichthys* (?) sp. Cleveland Shale, Lorain County, Ohio. Visceral aspect of dorso-median belonging presumably to an immature individual. Original in Oberlin Museum. Very nearly natural size.

The chief peculiarity of this plate is the deep indentation of its lateral margins, but this is to be regarded merely as a specialization of the lobes occurring in the same region among other species, such as *D. ringuebergi*[1] for example, and also in the plate shown in Fig. 6. We may be sure that it had to do with the mode of articulation with the dorso-laterals, perhaps serving for the reception of a ridge given off from the latter. It would naturally be supposed from the figure that the anterior margin was entire, but we cannot avoid a suspicion that a sharply pointed projection in the median line has been broken off, since a similar fragment with associated bones on exhibition at Columbia shows such an anterior projection. Trachosteus, too, has the dorso-median cuspidate in front, but the plate is reduced in size to a mere caricature. Even the small dorso-median shown in Fig. 6, the original of which is preserved in the Oberlin College Museum, shows a broken extension in the median line anteriorly, which may originally have been pointed or triangular. We have reproduced a photograph of this shield, kindly furnished by Prof. A. A. Wright, for the sake of comparison with Fig. 5, as there are several points of mutual resemblance. In fact, the stamp of Titanichthys is so strongly impressed that we must regard the plate either as belonging to an embryonic individual of this genus, or else as representing a pygmy species essentially similar to the Titans. It has a strong anterior emargination, slender antero-external angles, and a relatively large posterior expansion of the dorsal surface, all of which characters are possessed in common with Titanichthys rather than with Dinichthys. Moreover, the antero-lateral margins are deeply lobed, and without question these sinuses are of corresponding nature with the incisions already noted in the dorso-median of *T. clarkii.* It will be understood that the carinal process has been broken away from both specimens, its point of attachment being just underneath the conspicuous posterior expansion of the shield.

Having now identified Newberry's "hyoid (?) or ventral plate" of *T. clarkii* as the dorso-median properly belonging to that species, the question arises, where is the shield to be placed which this author referred to *T. clarkii?* We can only answer, without having seen the specimen, that there is a strong presumption of its having belonged to *T. agassizii.* For we have already noticed that the shield in the latter species is without deep lateral incisions and has no triangular projection in front ; and moreover its form (see Fig. 4) agrees with Newberry's statement that "the dorso-median shield is rounded in outline, about two feet in diameter, much thinner than that of Dinichthys, and with a long and relatively slender process, which reaches backward and downward apparently to gain the support of the neural spines."[1] The large size of this particular specimen is, however, remarkable.

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[1] *Amer. Journ. Sci.* [3], vol. xxvii (1884), p. 477, Fig. 1.

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[1] *Loc. cit.* (1889), p. 130.

ERRATUM.

Through an oversight for which the author was not responsible, the cuts for Figs. 5 and 6 of Dr. Eastman's article on p. 766 of the October number were interchanged. The lowermost figure is the dorso-median plate of *Titanichthys clarkii* Newb., lacking the *carinal* instead of "cranial" process, and is reduced $\frac{1}{16}$ instead of $\frac{1}{21}$ natural size.